Sensor Anomaly Mitigation in DM

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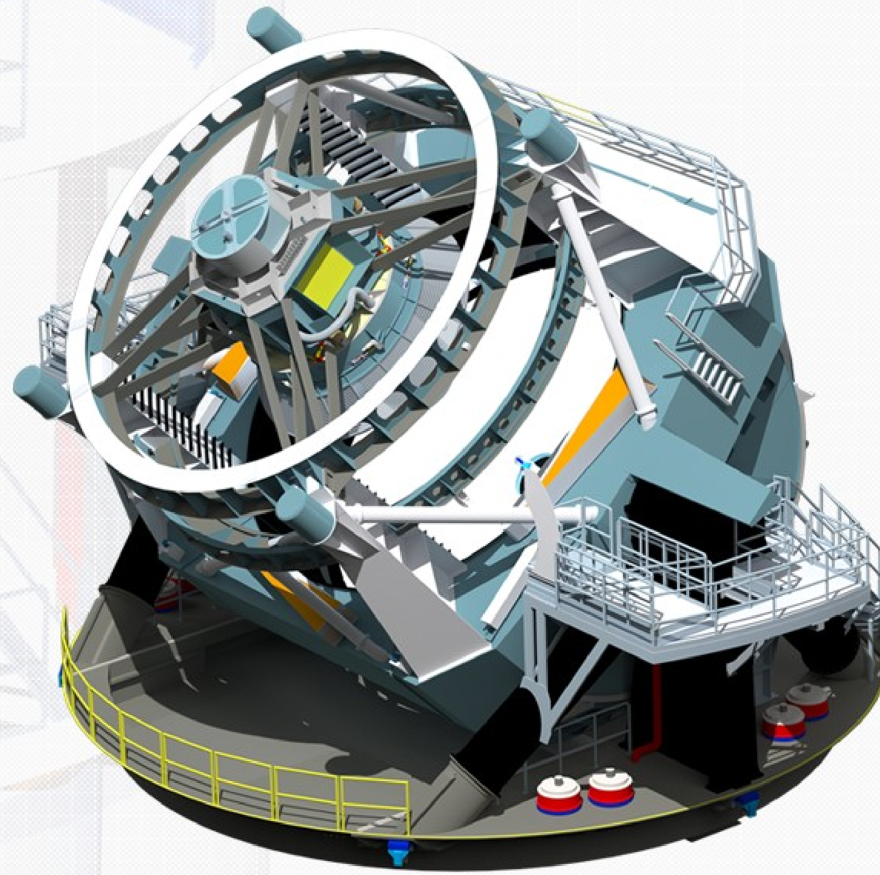

Last Kiloparsec Systematics
12/14/2015-12/15/2015 | UC Davis

Overview

- What pipelines algorithms assume.
- What we already know we *can't* assume anymore.
- What's scary for us, and what's not.
- Selected sensor anomalies and our (vague) plans.

Decomposing the Observational System

true sky

↓

convolve with PSF

↓

transform by WCS

↓

scale by photometric efficiency

↓

add noise

↓

observed image

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Approximations

Fundamental

- PSF is locally constant (on the scale of an object)
- WCS is locally affine (on the scale of an object)

Convenient

- Noise is uncorrelated
- PSF is Nyquist-sampled
- All operations are wavelength-independent within a filter

Existing Inconveniences

- PSF *will* be wavelength-dependent within a filter.
  - New territory for WL; success depends on being able to separate the optical and atmospheric components of the PSF.
  - Will include DCR, so WCS doesn't have to (we're hoping WCS will not be wavelength-dependent).
- Some images will be undersampled.
  - We'll include these multifit; we may or may not be able to include them in coadds.
- We'll likely have to address correlated pixel noise at some stages of processing, but we don't know how much or how well.

Sensor Anomaly Threat Level

SEVERE

HIGH

ELEVATED

GUARDED

LOW

Does the effect:

- break our decomposition of the observational system?
- break a fundamental approximation?
- break a convenient approximation?
- affect many pixels, or just a few?
- add many new parameters we need to constrain from the data?
- definitely affect LSST sensors?

Brighter-Fatter

HIGH

- Doesn't fit into our decomposition of the system *at all:* it's not a convolution or a coordinate transformation.
- Physical models can't yet explain everything we see (until recently, perhaps?)
- Affects every pixel.
  - Probably insignificant for most WL source galaxies.
  - Definitely affects stars we'd like to use for PSF modeling.
- Not clear how to separate this from the PSF in detail (especially pixel convolution and charge diffusion terms).
- Cross-terms with other sensor effects concerning.

Brighter-Fatter Mitigation

true sky

↓

convolve with PSF

↓

transform by WCS

↓

scale by photometric efficiency

↓

add noise

↓

brighter-fatter

↓

observed image

- Develop parameterized model from laboratory experiments and physical simulations.
- Constrain parameters from flat field and sciences images.
- Correct as much as possible by redistributing flux in ISR (existing methods work at 90% level).
- If necessary, revert pixels and include in forward modeling of star images when modeling the PSF.

Edge Distortions

GUARDED

Pure WCS effect, frozen in chip, small number of parameters in model.

- May break local/affine approximation at the very edge.
- Affects a small number of pixels, assuming amplifier edges are not affected or much less affected.

Strategy:

- Use laboratory experiments and physical model to develop parameterized model, include in WCS.
- Fit parameters to relative star positions and flat fields.
- Mask regions with non-affine local distortions.

Tree Rings

ELEVATED

Pure WCS effect, frozen in chip, large number of parameters in model (but tons of data to constrain them).

- Unlikely to break local/affine approximation?
- Affects a large number of pixels.
- May be too small to matter for LSST sensors.

Strategy:

- Use laboratory experiments and physical model to develop parameterized model, include in WCS.
- Fit parameters to relative star positions and flat fields.

Pixel Area Variation

SEVERE

Pure WCS effect, frozen in chip, very large number of parameters in model (but tons of data to constrain them).

- **Unknown** whether this breaks local/affine approximation. If it does, this is a *very* serious problem. If it doesn't, it's essentially the same as tree rings.
- Affects a large number of pixels.

Strategy (if it doesn't break local/affine approximation):

- Use laboratory experiments and physical model to develop parameterized model, include in WCS.
- Fit parameters to relative star positions and flat fields.

What if we break the fundamental approximations?

- Just keep forward modeling:
  - We can't commute PSF convolution and WCS transformation operations.
    - Just a single hybrid transfer function?
    - Multiple convolutions and transformations applied in sequence?
    - Do the approximations only fail at the very end?
  - We can't include the pixel as part of the PSF.
  - We can't use FFTs.
  - We can't use Sinc (actually Lanczos) interpolation.
- Redistribute flux to restore local/linear properties.
- ~~Rewrite downstream algorithms to work on surface-brightness images.~~ *PROPOSAL IN PRESENTATION WAS BASED ON A MISINTERPRETATION OF DES PLANS; DISREGARD.*

Probably Easier Problems

- Crosstalk **LOW**
  - Easy to model, easy to correct.
  - Potentially computationally expensive – but not really that bad in the scheme of all DM processing.
- Nonlinear pixel response **LOW**
  - Once we know how it varies between pixels, easy to model and correct.
- Charge Transfer Efficiency **LOW**
  - Currently assumed negligible for LSST.
  - Lots of literature if it isn't.
- Persistence **LOW**
  - Currently assumed negligible for LSST.

Bad Ideas to Avoid (Editorial)

- *Relying on dithering to "average down" systematics.* Dithering is important for constraining model parameters, but relying on it to actually mitigate effects directly will make "usable data" selection a nightmare.
- *Addressing sensor effects in catalog space.* This is the last recourse of the unprepared, and it will be almost impossible to back out everything the image processing pipeline will have already done wrong.
- *End-to-end simulations of how sensor anomalies affect shear.* Better to focus on depth rather than breadth, as it's very hard to predict the detailed behavior of a complete shear pipeline without actually building it.
- *Constraining properties of individual sensors using laboratory experiments.* In general, we should focus laboratory work on defining models that are valid for all sensors, and constrain their parameters from science and calibration data.

Priorities for Future Work

- Do pixel area variations break the local/affine approximation at a significant level?
  - What's “local” enough?
  - What's “affine” enough?
- What do we do if pixel area variations *do* break the local/affine approximation?
- Figure out the last ~10% of brighter-fatter correction (is it just flux-dependent charge diffusion?)
- Work out the details of constraining frozen WCS effects from flat fields and astrometry.
- Verify that “frozen in sensor” effects really are.
- Verify that wavelength dependence (within a bandpass) isn't important.
- Investigate compound lateral field problems (e.g. brighter-fatter on the edge).